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Notes on *Ergasilus* Parasites from the New Brunswick, New Jersey, Area, with a Check List of All Species and Hosts East of the Mississippi River.

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INTRODUCTION.

The members of the genus *Ergasilus* represent the most undifferentiated of all the copepod parasites and clearly show a possible line of evolution from the free-living forms to the very specialized parasites that are to be found in other families and genera. Even in the genus itself one finds the transition taking place, and *E. chautauquaënsis* (which has never been found as a parasite) to *E. elegans*, which is parasitic only after the eggs begin to develop, and on to the other forms where the females are parasitic after they have become sexually mature.

The main characteristics of the genus are its cyclops-like appearance; 2nd pair of antennae enlarged and prehensile, 1st antennae six-jointed; first thoracic segment and head fused to form a large carapace; five pairs of swimming legs; the first four biramose, the fifth pair very degenerate and uniramose. Egg sacs are similar to those in *Cyclops*. The genus is typically fresh-water, though some ergasilids are to be found in brackish and marine waters. The type species of the genus is a very common European species, *E. sieboldi*, established by Nordmann in 1832.

These parasites are generally found clinging to the gill filaments, but one species, *E. megaceros*, has been found in the nasal fossae of the Fulton cat, *Ictalurus anguilla*, and another, *E. elongatus*, has been found attached to the bony gill rakers of the spoonbill cat, *Polyodon spathula*. At the present time they have been found to infest all of the major groups of fresh-water fishes and it is likely that no species of fresh-water fish is entirely free from the possibility of becoming a host. As far as is known, fishes are the only hosts on which this genus has ever been found. (See Mueller, 1936; Tidd & Bangham, 1945; Wilson, 1911, 1916, 1925, 1932; Wright, 1844.)

The males of *Ergasilus* are free-swimming throughout their lives. They are small and easily overlooked in plankton samples and consequently few of them have ever been described. The chief distinguishing characteristics in the males are the powerful maxillipeds, which are lacking in the females, and the small, weak second antennae.

The females are free-swimming during their early developmental stages and only attach themselves after mating. It is generally concluded (Wilson, 1911) that mating takes place only once while the female is still free-swimming. The sperms are stored in the semen receptacle and fertilize the eggs as they pass out into the ovi-sacs.

The breeding season apparently extends throughout the summer months. The length will vary from season to season, or from one region to another, depending on favorable water temperatures. In this area females were observed with fully extended egg strings on March 31. In the laboratory the incubation period was found to be around eight weeks, which is about the period of time observed by Wilson ("eight to nine weeks"). Henderson (1926) in her paper on *E. lucionercarium* from Canada, stated that it is likely that the females carry their egg strings throughout the winter. This is not the case in Westons Mills Reservoir, but it may be that in Canada, where the summer season is considerably shorter, the last batch of eggs does not get the chance to develop before cold water temperatures come and consequently must be carried over until the warmer temperatures of spring. In New Brunswick the breeding season is over by the middle of November.

OBSERVATION ON EPIDEMIC OF *Ergasilus* ON FISHES IN THE WESTONS MILLS RESERVOIR, NEW BRUNSWICK, N. J.

During the latter part of November, 1947, fishermen began to notice large numbers of fish dying in Westons Mills, a reservoir from which New Brunswick obtains its water supply. Local residents estimated that the fish were dying by the "thousands," and indeed the number of dying fish was so great

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as to attract large flocks of sea gulls from the nearby Raritan River. The fish affected were apparently only two species, calico bass, *Pomoxis sparoides,* and bluegill, *Lepomis macrochirus.*

Some of these fish were brought to the Rutgers University Zoological Laboratory where they were examined for possible parasitic infestations. No intestinal parasites were found in excessive numbers nor did there appear to be any injury of body tissues, either external or internal. The gills appeared to be covered with an unusually heavy coating of mucus and microscopic examination revealed great numbers of copepod parasites of the genus *Ergasilus.* The blue color of these organisms, the three knobs on the inner edge of the second antennae towards the distal end, and the fact that they were all found in between the gill filaments seemed to indicate conclusively that these were of the species *caeruleus.* The hairs and spines on the appendages, along with other general morphological characteristics, were not quite in accord with Wilson's *caeruleus,* but there seemed to be a considerable amount of variation in this genus, depending on geographic location (Mueller, 1936). Wilson (1911) considers *caeruleus* a parasite of the vegetative Centrarchidae, and gives the explanation that the copepods on these fishes must locate themselves between the gill filaments to escape the discomfort and irritation to their gills from bits of vegetation.

A number of trips were made to the reservoir to collect fish during this period. Oxygen determinations were made at all depths and at no time was the O_2 concentration less than 10 ppm. Most of the fish were alive when captured. They could easily be spotted as they swam feebly on their sides on the surface of the pond. It was possible to come up alongside these fish in a boat and pick them up by hand. Occasionally a fish would sound on approach, but only to rise slowly to the surface after a short interval. On the first of such trips about a dozen fish were collected and taken back to the laboratory. These were placed in a well-aerated aquarium. At first they seemed almost dead—all lying motionless on their sides, with only an occasional movement of a fin. The next day, however, they seemed fully recovered and all were swimming about apparently quite normal. A few of these examined at this time were found to have a very heavy infestation.

In brief, the meager facts obtained on the epidemic from Nov. 27 to Dec. 10, 1947, can be summarized as follows:

1. Many calico bass and bluegills died during this period. No official estimates could be obtained, but laymen who observed the phenomenon estimated the deaths to be in the thousands.
2. One calico bass died for every ten bluegills. These were apparently the only fish affected.
3. All fish that were infested by these parasites appeared to have a heavy coating of mucus over the gills.
4. Estimated number of parasites on each fish was 250-300.
5. Age group (as determined by scale readings) was 1-2 years.

During the late fall of 1948 these observations were continued. A large fish trap was constructed and set in deep water as soon as ice covered the reservoir. All of the species of the Centrarchidae as well as one yellow perch were examined. Later in the year the fish were obtained by seining and from fishermen.

In this survey the large-mouth bass, *Micropterus dolomieu,* was found to be parasitized by a second species, *E. centrarchidarum.* This species is generally larger, broader, and found on the outside of the gill filaments, in contrast to *caeruleus* which is found between the gill filaments. In addition, there are no knobs on the inside surface of the distal end of the second pair of antennae.

Again there were morphological differences from Wilson's description of *centrarchidarum* and this phase of the work will be discussed in a later paper. Both species had the blue pigment but *centrarchidarum* was never as deeply pigmented as *caeruleus.* Strangely enough, both species had the same hair and spine formula on their appendages. This is: 1st exopod, I-0; 0-1; II-5, endopod 0-0; 0-1; II-3: 2nd exopod, 0-0; 0-1; 0-6, endopod, 0-1; 0-2; I-4: 3rd exopod, 0-0; 0-1; 0-6, endopod, 0-1; 0-2; I-4: 4th exopod, 0-0; 0-5, endopod, 0-1; 0-2; I-3.

In addition to the sampling of fish from Westons Mills, two other bodies of water in the New Brunswick area were sampled. These included the lower section of the Delaware-Raritan Canal and the small pond in Johnson's Park. The bluegills and calico bass in Johnson's Park were found to be free of ergasilids but the canal proved as fruitful as the reservoir. A summary of the fish examined is given in Table I.

Some interesting facts are foreshadowed in Table I. Although the amount of sampling from both bodies of water was not extensive enough to reveal fully the actual condition, nevertheless the methods by which these fish were obtained and the period of time over which the sampling was made certainly indicate the trend that one might expect to find if a more extensive sampling were to be taken.

For example, only five large-mouth bass were obtained—but under totally different conditions and at various times. The fact that all five had infestations does not indicate that all the bass are parasitized, yet one would expect to find a high percentage of the bass serving as hosts to these parasites. On the other hand, not once during this entire period of research has there ever been found a pumpkinseed infested with these copepods. Certainly one can say that for this species the incidence of parasitism is very low.

Again, viewing the information in the same light, one should expect the bluegills to be parasitized about 50% of the time in

TABLE I.

Result of the Samplings from Westons Mills and Delaware-Raritan Canal from Nov. 30, 1948-July 30, 1949.

Name	*Total No. Caught*	*Percent of parasitism*	*Average Length*	*Length Range*
Calico bass*	5	100%	5.79″	4″–7″
Bluegills	15	60%	5″	2″–7¾″
Pumpkinseed	6	0%	4″	3″–5″
Large-mouth bass	5	100%	6.4″	2½″–12″
Yellow perch	1	0%	7″	7″

* The highest infestation noted was on one calico bass 5¾″ in length; 259 *caeruleus* were counted on this fish.

Westons Mills and the Canal. No data on calico bass could be obtained from the Canal but from the available information it would seem that these fish have become the most heavily infested in Westons Mills, not only in number of individuals but in number of parasites per fish. This is significant, for although the calico bass was found to be the most heavily infested as well as the most commonly parasitized fish, the epidemic of 1947 killed only one calico bass to ten bluegills. Unfortunately, here also, too little information is at hand. On the basis of the present data, however, there seems to be two logical explanations for this:

1. The calico bass are more resistant to the infestation of these gill parasites than are the bluegills and have been able to build up a resistance.
2. All the bluegills left are those that have built up a resistance to these parasites, or those that were only slightly parasitized.

Both fish are to be found in the same general type of environment and both have similar food habits, so apparently these two factors may be discounted.

Pathogenesis.

There has been a great deal of controversy over the extent of damage done by the ergasilids, as well as exactly what kind is done. Wilson (1911) states that "Living as they do upon the fish's gills, there can be but little doubt that they feed upon blood." Halisch (1939) in his observations on *E. sieboldi* and *E. minor* on the gills of tench states that extra-intestinal digestion is important and that much more tissue is destroyed than is ingested by the parasitic copepod. Blood may be taken in. Fungi may grow in the lesions.

In contrast to these two observations, Henderson (1926), in her work on *E. lucioperca rium*, observed that "The gills may be heavily attacked without affecting the health of the fish. It is a harmless parasite, which, while it only benefits the unbidden guests, causes no lesions and consequently does no injury to the host." (If this is the case it should not even be called a parasite, but a commensal). She goes on to explain how, in her opinion, it is impossible for the parasites to injure the gill tissue, since the mouth parts of these organisms are too weak to pierce the gill tissue.

One might suspect that the claw-like, prehensile, second pair of antennae of the parasite is capable of at least some damage to the gill lamellae, although the mouth parts may be too small to cause any injury. However, the observations in the present studies showed no evidence of mechanical injury; neither was there any evidence of digested gill tissue or blood in the intestine of the numerous copepods examined, even in females with ovaries full of developing eggs.

We agree with Henderson (1926) that these parasites in all probability feed on the excessive mucus produced under the condition of the parasitism, or the many minute mucus or bits of organic debris and bacteria in this viscid material. However, it is altogether possible that the parasites may feed on sera, straining out the corpuscles.

A close examination of the mouth parts of these ergasilids will reveal the mandibles and second maxillae heavily fringed with setae. These would seem ideal for feeding on mucus or bits of organic debris and bacteria but hardly suitable for feeding on blood. Any pathological conditions of the gills may cause the mucus glands to secrete an excessive amount of mucus (Nigrelli, 1949). This has been especially apparent during infestations of trematode gill parasites. This condition has also been observed on many of the fish that were infested with these copepods[2]. It may be that an excess mucus secretion over the surface of the gills may lower the efficiency of the gills to absorb the dissolved oxygen in the water. Under normal water conditions when there is sufficient oxygen and all the chemical and physiological factors are in proper balance, this may not have any deleterious effects. However, if, for example, a factor such as the CO_2 concentration in the water should be increased, it might be sufficient to reduce the efficiency of the gills in absorbing the dissolved oxygen and so cause the fish to die of suffocation.

The highest death rate has been found among the younger fishes and it is the

[2] It must be kept in mind that the heavy coating of mucus which seems to accompany fish that are heavily infested with this parasite does not mean too much in itself. Fish that have been placed in preservative or that have died from other causes may show the same condition. Moreover, some fish that were heavily infested did not have an excess of mucus covering the gills. In such cases these fish exhibited no symptoms whatsoever and appeared perfectly normal. Apparently, there is a physiological balance here that is very delicately adjusted and which can be thrown out of balance only under certain specific conditions.

TABLE II.

Check List of the *Ergasilus* Found East of the Mississippi River.

Names and Synonyms	*Hosts*	*Localities Studied*	*Remarks*
E. caeruleus Wilson Synonyms: *E. confuscus* Bere *E. skryabini* Mueller	Yellow perch Trout perch Wall-eyed pike Gray pike, Blue pike Rock bass, Calico bass White bass Warmouth bass Crappie Green sunfish Blue-spotted sunfish Pumpkinseed Bluegill Lake trout Cisco, White fish Sucker, Long-nosed gar	Lake Mendota Trout Lake region Lakes Erie & Michigan Oneida Lake Mississippi River, Iowa	
E. centrarchidarum Wright	Rock bass, Calico bass, Large-mouth bass, Small-mouth bass, White bass, Warmouth bass, Green sunfish, Bluegill, Crappie, Pumpkinseed, Sunfish (?) Wall-eyed pike, Gray pike, Sauger, Silversides, Smelt, *Microgadus tomcod*	Lake Erie Lake Michigan St. Lawrence River Watershed Lake Champlain Black Lake, N. Y. Lakes St. John & Chibogamo, Quebec St. Andrew's Bay, N. B. Lake Maxinkuckee, Ind. Mississippi River, Iowa Clewiston, Fla. Woods Hole	
E. chautauquaënsis Fellows		Lake Champlain Lake Mendota Fairport, Iowa	Has never been found as a parasite, but may be like *elegans*
E. cotti Kellicot	Rainbow darter Sculpin—*Cottus bairdii*	Lake Erie Westerville, Ohio	
E. elegans Wilson	*Ameiurus* sp. Northern black bullhead Channel catfish Short-nosed gar Long-nosed gar	Lake Okeechobee Myakka River & Canals Peace River, Fla. Mississippi River, Ia.,	Parasitic only after eggs begin developing
E. elongatus Wilson	Spoonbill cat	Mississippi River, Iowa and Illinois	
E. funduli Krøyer	*Fundulus ocellaris*	New Orleans	Salt and brackish water
E. labracis Krøyer	Striped bass	Woods Hole Baltimore	Marine
E. lanceolatus Wilson	Gizzard shad	Cumberland River, Ky.	
E. lizae Krøyer	Common killifish Gulf killifish Broad killifish Striped mullet White mullet	Englewood, Fla. New Orleans	Salt and brackish waters
E. luciopercarum Henderson	Pike perches	Lake St. John Lake Chibogamo, Que.	
E. manicatus Wilson	Silversides Smelt Two-spined stickleback Top minnow (*Gambusia holbrooki*) *Jordanella floridae*	Englewood St. Andrew's Bay, N. B. Woods Hole Along Atlantic Coast	Marine

Names and Synonyms	*Hosts*	*Localities Studied*	*Remarks*
E. megaceros Wilson	Fulton cat Fall fish	Oneida Lake, N. Y. Mississippi River, Iowa	Found in the nasal fossae and spiracles
Synonym:			
E. fragilis Mueller			
E. mugilis Vogt	Striped mullet	Beaufort, N. C.	Marine
E. nigratus Wilson	Large-mouth bass	Mississippi River, Iowa	
E. osburni Tidd & Bangham	Burbot	North Central States	
E. versicolor Wilson	Fulton cat Red-mouthed buffalo fish Channel cat	Mississippi River, Iowa Florida Lake Erie	
Synonym:	Common brown bullhead Mudcat	Lake Maxinkuckee	
E. celestis Mueller	Skip jack Yellow cat Eel cat		

younger fishes that would require the greatest amount of oxygen (in proportion to the gill area), due to their greater metabolic activity. At the same time it is the younger fishes that are more susceptible to attacks from disease and parasites since they are using all their available energy toward growth. Wilson states that it is the young fish that are most heavily parasitized and this is probably true—especially during an epidemic. However, larger fish may also be quite heavily parasitized. (See Table 1).

The ergasilids on the large-mouth bass were never very abundant—never more than thirty on any individual. Although Wilson (1916) mentions fish fatalities from the ergasilids he does not mention which species of copepod causes death, nor which species of fish are killed. In checking all the literature on *centrarchidarum*, never were their numbers found to be as great as for *caeruleus*. Therefore, one wonders if *caeruleus* is not the only one that may appear in such numbers as to bring about the death of a fish.

This leads us to speculate on how many ergasilids must be present on a fish to cause death. It would seem that numbers that lead to the death of a fish at one time, appear to have no effect at another. However, during the epidemic of 1947 none of the dead fish had less than an estimated 250 copepods. Whether fewer parasites can bring about the death of a fish remains to be determined by further study.

It is apparent from the literature that *E. centrarchidarum* is the most widespread parasite and probably the best known. It has been found in all the main regions studied, including the marine habitat, but it has not been found on as many hosts (16) as has *caeruleus* (19), nor on as great a variety.

Caeruleus has not been found in all the areas that have been studied and so far has proved to be an exclusively fresh-water parasite. Additional research may also reveal that *caeruleus* is more widespread than *centrarchidarum*. It is unfortunate that most of the workers in this field have failed to make clear whether *caeruleus* has always been found between the gill filaments of its host. If it is found between the gill filaments of such clear-water fishes as the lake trout, cisco and white fish, certainly Wilson's explanation for their being found between the gill filaments is not substantiated.

E. versicolor is apparently third in abundance and seems to be more specific in its parasitism.

Many of the *Ergasilus* have only been found on one or a few hosts, but it is still too early to state definitely that they are specific for only those hosts.

Conclusions.

1. It seems quite likely that *Ergasilus* may indirectly cause death to fish, although it probably seldom causes extensive damage to any given fish population.
2. Young fish (1-2 years) are apparently the only ones on which these parasites may prove fatal. Although infestations have been found to be equally high on all age groups, more young fish appear to be heavily infested than older ones.
3. Ponds where the fish are overcrowded or that are small in area seem to be the only places where infestations become high enough to cause death.
4. Ergasilids do not feed on blood, but probably on mucus or bits of organic matter found in the viscid material.
5. Death of fish is probably due to a delicate physiological imbalance affecting the diffusion of oxygen through the gill tissues.

6. *E. caeruleus* can always be distinguished from *E. centrarchidarum* by the three knobs on the second pair of antennae, and by the fact that it is always found in between the gill filaments. Variations among these copepods are exceedingly great.
7. Although Wilson considers *E. caeruleus* a parasite of the plant-eating Centrarchidae, it is also found on species that are quite carnivorous and not generally found among aquatic vegetation. It undoubtedly is found most commonly on fishes that typically inhabit an environment of aquatic vegetation, such as the bluegill and calico bass.
8. Though *centrarchidarum* and *caeruleus* have often been found on the same fish (Wilson, 1911, 16), they were never observed together in the New Brunswick area nor was *centrarchidarum* ever observed on either bluegills or calico bass in this area. Neither was observed on any but the above species of fish.
9. It may be that certain factors, chemical, physical, physiological and environmental, or a combination of these, determine which hosts may be parasitized.
10. No reason could be found to explain why the pumpkinseed, *Lepomis gibbosus*, is free from these copepod parasites in this region.

Summary.

An epizootic in Westons Mills Reservoir which caused the death of many bluegills and calico bass was investigated.

A copepod parasite, *Ergasilus caeruleus*, was believed to be the indirect cause of the death of these fish. Apparently, metabolic wastes from the copepod or irritation to the gill tissues causes an excessive secretion of mucus. This mucus may lower the efficiency of the gills, so that when certain other factors are not in proper balance the fish will suffocate.

Large-mouth bass were found to be infested with another species *E. centrarchidarum*.

A brief survey of two other bodies of water in the New Brunswick area revealed that the incidence of parasitism from these ergasilids is quite high for bluegills, calico bass and large-mouth bass, but does not seem to be present on the pumpkinseed.

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